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WISDoM-SD: Wireless IPTV service distribution over mesh mode via space diversity

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ABSTRACT

In this paper, an alternative solution for distribution of IPTV service in a wireless environment is proposed. Considering the data rate requirements of the IPTV service and challenges in distribution of the service due to wireless environment, the proposed model is built on the Mesh operating mode of the standard IEEE 802.16 (a.k.a, WiMAX). Besides the high data rates provided by the WiMAX technology, the capability of relaying transmissions and the adaptability to changing environment brings the WiMAX Mesh mode as a viable alternative to the infrastructure based models.

In WISDoM-SD, the standard WiMAX Mesh mode is modified in order to meet the strict delay requirements of the IPTV service and improve capacity by enabling transmission of more IPTV channels to more subscribers. Accordingly, transmissions are carried over only high data rate links and connections with up to two hops to the BS are allowed. Additionally, benefiting from space diversity information, parallel transmissions are utilized to save transmission slots, and allow serving more users. The results of the simulations show that, for the given delay constraints, the WISDoM-SD model improves capacity compared to the standard WiMAX Mesh mode at the cost of omitting a few nodes (less than 1% of total nodes) for which the experienced channel quality is too low for IPTV service anyways.

1. Introduction

The rapid advances in telecommunication technologies have increased the interest in advanced Internet applications. Providing digital television over the Internet Protocol (IP) at low costs, the Internet Protocol Television (IPTV) [1–3] has become one of the most popular multimedia video streaming applications in recent years. This bandwidth hungry application is also expected to play a key role for future business growth of the next-generation broadband Internet technologies. Due to competitive pressure in the telecom market, many operators have already expanded their services to triple-play (data, voice, and video services) or even quadruple-play services (triple-play services plus mobility) on a single infrastructure to stay in the market and to prosper as well [2,4].

The wireless standard IEEE 802.16, so called WiMAX (World Interoperability for Microwave Access) [5], is one of the most promising next-generation wireless technologies, which has the potential to provide IPTV service effectively with high data rates and long transmission ranges supported by the recent IEEE 802.16 m WiMAX systems [6]. Although some advanced wired methods such as Digital Subscriber Line (DSL), cable, or fiber may meet the bandwidth requirements for the IPTV service, a wired infrastructure is required for these models to operate. Considering the geographical structure of the environment, it may be difficult to deploy such an infrastructure. Furthermore, deployment of a wired network is more expensive compared to wireless technologies. Therefore, there is a great interest in alternative broadband wireless techniques. At this point, the ease of deployment and

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adaptability to changes in topology bring WiMAX as a reasonable alternative to the wired techniques [7–9].

There are basically two operating modes defined in WiMAX (starting from IEEE 802.16d standard), namely the Point-to-Multipoint (PMP) and the Mesh operating modes. Among these two, the PMP mode has a similar infrastructure to IEEE 802.11 networks [10]. There exist two types of devices in the PMP mode: the Base Station (BS) and the Subscriber Station (SS). The BS manages the network traffic, and the mobile (e.g., pedestrians or vehicles) and fixed (e.g., buildings) SSs have to connect directly to the BS in order to receive service. Similar to the PMP mode, there are two types of devices in the Mesh mode, namely the BS and the Mesh Subscriber Station (MSS). In the Mesh mode, the BS controls the network traffic similar to the BS in the PMP mode. However, different from SSs in the PMP mode, the MSSs in the Mesh mode have the ability to connect to other subscribers and have their transmissions relayed over those subscribers in an ad hoc manner.

Considering the high data rate requirement for the IPTV services and the limited spectral resources, the establishment of high data-rate connections is essential to meet the delay requirements for the IPTV service and distribute the IPTV service effectively. However, in metropolitan areas, it is generally hard to establish a high data-rate connection to the BS directly. A station may even fail to establish any connection to the BS at all due to geographical structure of the environment. At this point, utilization of the Mesh mode operation plays the key role of enabling the subscriber stations, which are not able to connect to the BS using a high capacity modulation coding scheme, to receive IPTV service effectively. Via the Mesh mode operation, these stations can connect to an available MSS which has a high data rate connection to the BS and this MSS can relay their transmissions.

The delivery mechanism also plays a vital role for the distribution of IPTV service over WiMAX. Since there is a requirement for transmission of the video bitstreams of a TV channel to multiple users, multicasting can be adopted for efficient delivery of this same data to multiple receivers simultaneously. Clustering the users who are tuned to the same TV channel in a single multicast group, the whole group can be served with a single transmission consuming less bandwidth [11].

In wireless networks, all users in a multicast group may not necessarily experience the same channel conditions. While a user's channel quality may enable high bit-rate modulations at high signal-to-noise ratio (SNR), a bad channel quality and low SNR may enforce the use of a more robust but low capacity modulation scheme. As mentioned in [4,11], this multiuser channel quality diversity is considered as one of the biggest challenges in multicasting in wireless environments.

The multiuser channel diversity problem can be solved trivially by using separate data streams to broadcast a requested IPTV channel for each type of modulation used by subscribers requesting this channel. As a result, the same data for an IPTV channel is broadcast multiple times using the requested modulation-coding schemes for the same multicast group. Considering the limited spectral resources, these retransmissions of the same data degrades the performance of the network significantly.

In [4,12], the authors combine layered video approaches like Multiple Description Coding (MDC) [13] in the application layer and Super Position Coded Multicasting (SCM) [14] in the physical (PHY) layer to solve multiuser channel diversity problem effectively. These techniques reduce multicasting into a single transmission and thereby achieve significant bandwidth savings. However, there is a quality assurance problem with these models. It should be noted that each user receives service according to the maximum available instantaneous signal quality. From the network utilization perspective, this approach is equivalent to forcing all the users to communicate with the more robust, low capacity modulation schemes. This approach also constitutes a problem in practice since users who can be served at most in SDTV quality due to bad channel conditions will be unwilling to pay the same price with those receiving in HDTV quality. Moreover, these models do not help the users who are unable to establish any connection to the BS at all.

In the literature, there are also other approaches like [15,16], which aim at avoiding retransmissions due to multiuser channel diversity via cooperative transmissions and while enabling access to the uncovered users. Although the models address effective distribution via cooperation within the multicast group, an important problem with these models is the instability in path delays. The cooperation is done only within the multicast group. These models do not consider the condition in which the whole multicast group is positioned such that the transmission from BS to the relay nodes can only be accomplished over low data-rate links. Similarly, the users within the multicast group may be positioned such that the relaying (i.e., cooperation) can only be carried over low data-rate links. Considering these two possibilities, which significantly degrade the network performance, tolerable delay limits for the IPTV application can easily be exceeded. Therefore, stable distribution models with less deviating path delays should be utilized. Additionally, instead of reserved cooperation periods for single multicast groups, different multicast groups may cooperate simultaneously for available conditions. Thereby, the contribution of the parallel transmissions can be significantly increased. In this paper, we propose the Wireless IPTV Service Distribution over Mesh Mode via Space Diversity (WISDoM-SD), a common relaying phase (the counterpart of cooperation phases in [15,16]), which includes the whole network (with relayers of different multicast groups).

Taking these approaches into consideration, we extend our previous work in [17] and propose an alternative IPTV distribution model, which improves the multicast and the Mesh mode operation features of WiMAX. The spectral efficiency of the system is improved by utilizing a two-hop multicasting method using a single enhanced (i.e., high capacity) modulation-coding scheme at each hop instead of utilizing a low capacity modulation in single hop. The proposed model utilizes the Mesh mode operation to support the users who are either unable to connect to the base station at all or can connect only using a low capacity modulation scheme. Additionally, in the proposed model, the